An Overview of NPP VIIRS Pre-launch and On-orbit Calibration and Characterization

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Outline

- VIIRS Instrument
- Pre-launch Calibration and Test Data Analysis
- Post-launch Activities
- Summary

NPP VIIRS pre-launch calibration and characterization effort included contributions from NASA calibration team, Aerospace, MIT/LL, UW, Raytheon, and NGC; VIIRS post-launch calibration and characterization will be performed by the SDR team managed by NOAA STAR with contributions from different groups.

This presentation focuses on activities supported by the NASA's team

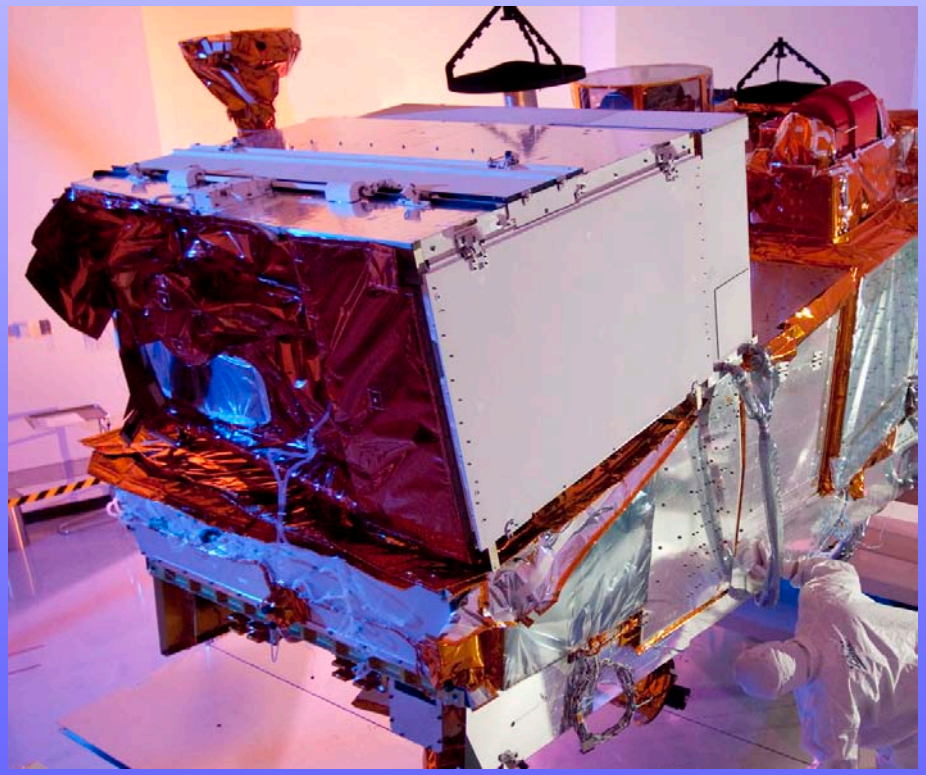
Visible Infrared Imaging Radiometer Suite

Description

- **Purpose:** Global observations of land, ocean, & atmosphere parameters at high temporal resolution (~ daily)
- **Predecessor Instruments:** AVHRR, OLS, SeaWiFS, MODIS
- **Approach:** Multi-spectral scanning radiometer (22 bands between 0.4 µm and 12 µm), 12-bit quantization
- **Swath Width:** 3000 km

Status

- Successfully completed comprehensive TV performance testing at instrument and s/c levels
- Performance is nominal
- NPP PSR completed (Aug 17-18)
- Ready for October 25, 2011 launch



VIIRS Bands and Products

VIIRS 22 Bands: 16 M-Band, 5 I-Band and 1 DNB

VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
○ M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
○ M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
○ M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
○ M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
○ M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
○ M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000
M12	3.660 - 3.840	750	20	SAME	1000
○ M13	3.973 - 4.128	750	21 or 22	3.929 - 3.989 3.929 - 3.989	1000 1000
M14	8.400 - 8.700	750	29	SAME	1000
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000
I5	10.500 - 12.400	375	31 or 32	10.780 - 11.280 11.770 - 12.270	1000 1000
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000

○ **Dual gain band**

Similar MODIS bands

VIIRS 24 EDRs Land, Ocean, Cloud, Snow

Name of Product	Group	Type
Imagery *	Imagery	EDR
Precipitable Water	Atmosphere	EDR
Suspended Matter	Atmosphere	EDR
Aerosol Optical Thickness	Aerosol	EDR
Aerosol Particle Size	Aerosol	EDR
Cloud Base Height	Cloud	EDR
Cloud Cover/Layers	Cloud	EDR
Cloud Effective Particle Size	Cloud	EDR
Cloud Optical Thickness/Transmittance	Cloud	EDR
Cloud Top Height	Cloud	EDR
Cloud Top Pressure	Cloud	EDR
Cloud Top Temperature	Cloud	EDR
Active Fires	Land	Application
Albedo (Surface)	Land	EDR
Land Surface Temperature	Land	EDR
Soil Moisture	Land	EDR
Surface Type	Land	EDR
Vegetation Index	Land	EDR
Sea Surface Temperature *	Ocean	EDR
Ocean Color and Chlorophyll	Ocean	EDR
Net Heat Flux	Ocean	EDR
Sea Ice Characterization	Snow and Ice	EDR
Ice Surface Temperature	Snow and Ice	EDR
Snow Cover and Depth	Snow and Ice	EDR

*** Product is a Key Performance Parameter (KPP)**

Pre-launch Calibration and Characterization

- **NPP VIIRS (F1) testing program has completed all planned testing phases**
  - Ambient Testing: 06/20/07 – 11/30/07
  - Sensor TVAC Testing: 05/03/09 – 08/23/09
  - Spacecraft TVAC Testing: 03/10/11 – 04/25/11

- **NPP VIIRS pre-launch testing has provided necessary test data to calibrate and characterize sensor performance, and to establish a baseline for sensor on-orbit operations**
  - Radiometric: gains, dynamic range, gain transition, linearity, SNR/NEdT, uniformity, uncertainty, polarization sensitivity, RVS, …
  - Spectral: RSR or SRF (in-band and out-of-band), spectral band-to-band crosstalk, …
  - Spatial: LSF/MTF, FOV, BBR, …

Pre-launch Calibration and Characterization

- **NASA team has performed extensive test data analyses for VIIRS F1 performance evaluation and requirement verification**
  - Participated key technical meetings, reviews, working group activities
  - Supported on-site test data analysis during sensor and spacecraft TVAC calibration and characterization
  - Produced 296 data analysis reports and 191 technical memos:
    - EDU Test: 42 reports and 88 memos
    - F1 Sensor-level Test: 217 reports and 96 memos
    - F1 Spacecraft-level Test: 37 reports and 7 memos
- **All performance waivers have been evaluated by NGST and reviewed by NASA team**
  - Most waivers have small to negligible EDR performance impacts
  - Algorithm revisions and/or changes to Cal/Val tasks were added to support waivers

VIIRS F1 Performance Summary

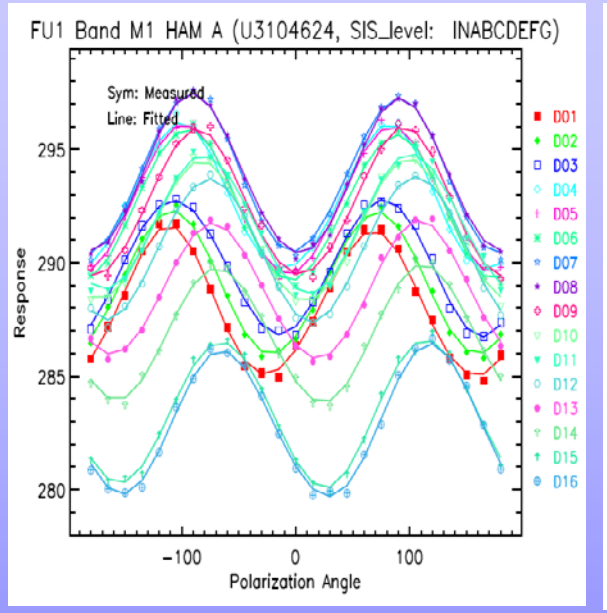
- **Radiometric**
  - VIIRS meets all Requirements for Signal to Noise Ratio, Dynamic Range, Gain Transitions, Linearity, Uncertainty, Stability and Polarization
  - Minor Variances for: M1, I2 and M8 not reaching specified maximum radiance, but no impact is expected from these non-compliances; detector uniformity with potential for striping (plan for post-launch fix, if needed)
- **Spectral**
  - Spectral Band Center, Spectral Bandwidth, Extended Bandwidth: Minor non-compliances are well characterized, no impact is expected.
  - Integrated Out-of-Band and Optical Crosstalk between VisNIR bands is extensively analyzed, and a mitigation plan is in place. On-orbit cal/val activities will assess efficiency of this mitigation plan.
- **Spatial**
  - IFOV, DFOV, HSR and BBR: Overall, performance meets Spec, with some detectors marginally out-of-Spec, but no impact is expected.
  - Band-to-Band Registration: Meet requirements, except for few detector pairs. On-orbit jitter might degrade BBR performance, but impact on product quality should be small.

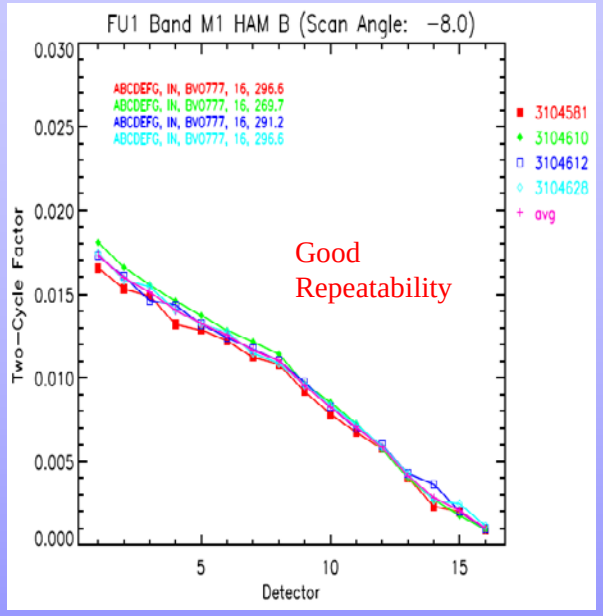
Other VIIRS F1 TV Issues and Concerns

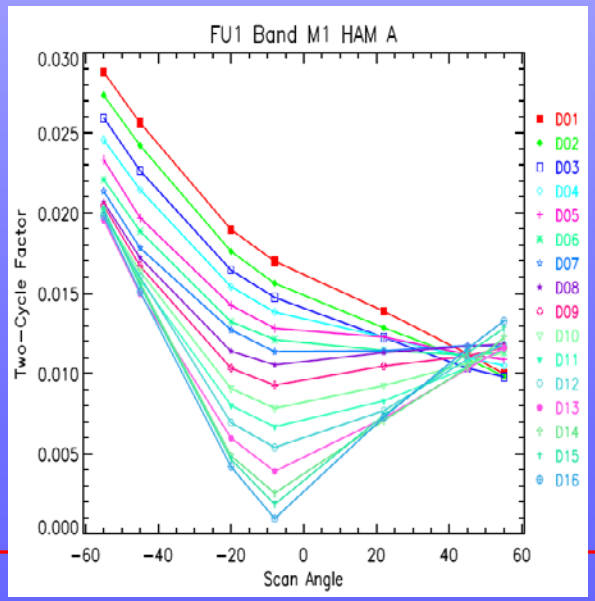
Issue	Description	Results and Impact
Spikes	Large sample spikes in the sensor signal observed for few bands during operational mode, only on A-side (Redundant) Electronics	No impact. This issue was never observed on Primary Electronics (B-Side). A plan to correct for this issue is in place.
Vignetting	Observed at FU1 TV Cold functional plateau, but goes away when sensor temperature warms up closer to TV Cold performance. Vignetting was not noticeable at any Performance plateau (Cold, Nominal, Hot).	No impact. Issue is not expected for on-orbit sensortemperatures. Program has provided STOP model #6 that includes vignetting compoent. This model can be used on orbit for any anomaly simulation and mitigation/correction approach if needed.
Gain bit crosstalk effect	Some bands calibration results are showing dependency on other bands gain status (High Gain vs Low Gain).	Small impact. This error will be considered in the final calibration error budget and impact assessments.
M1 and M11 tail and side lobe artifacts	LSF measurements have revealed side lobe features for M11 and M1. M11 side lobe might be attributed to field stop reflections, and M1 side lobe might be contributed to optical crosstalk.	Small impact. Need further modeling, to determine impact since on orbit illumination will have broad spectrum. It is not known how this side lobe is going to be varying on orbit (Ghosting shift if coming from mechanical part).
Gain transition noise	Increase of radiance non linearity and noise for dual gain bands at approximately 10% below Lmax.	No impact. Analysis done and have shown low impact on some EDRs. On-orbit scenes will be analyzed for impact assessment.

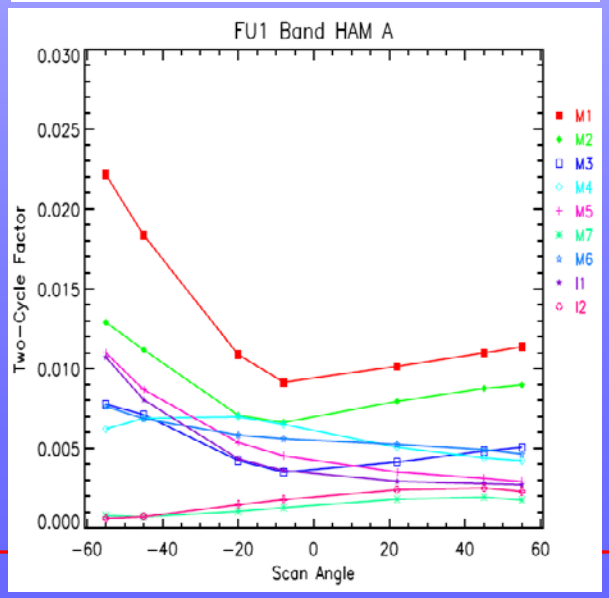
Valuable lessons for future JPSS and DWSS VIIRS Design and Test

VIIRS Polarization Performance





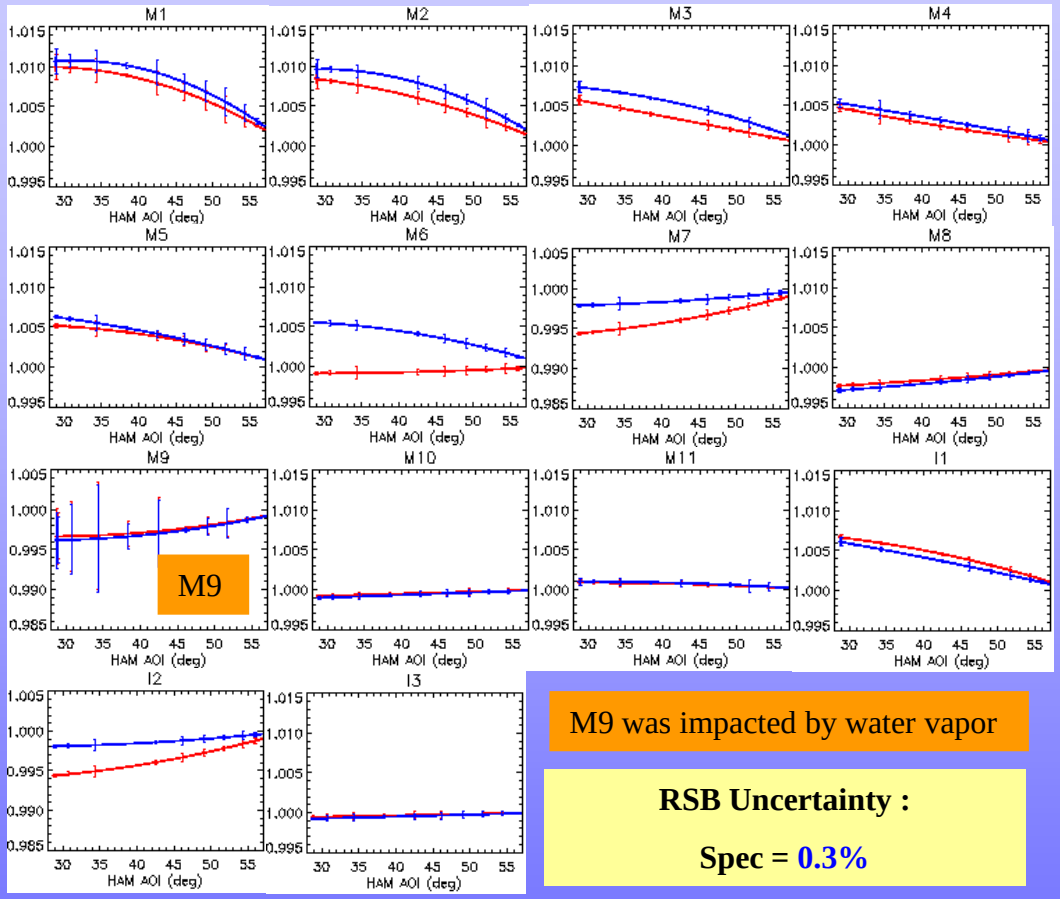


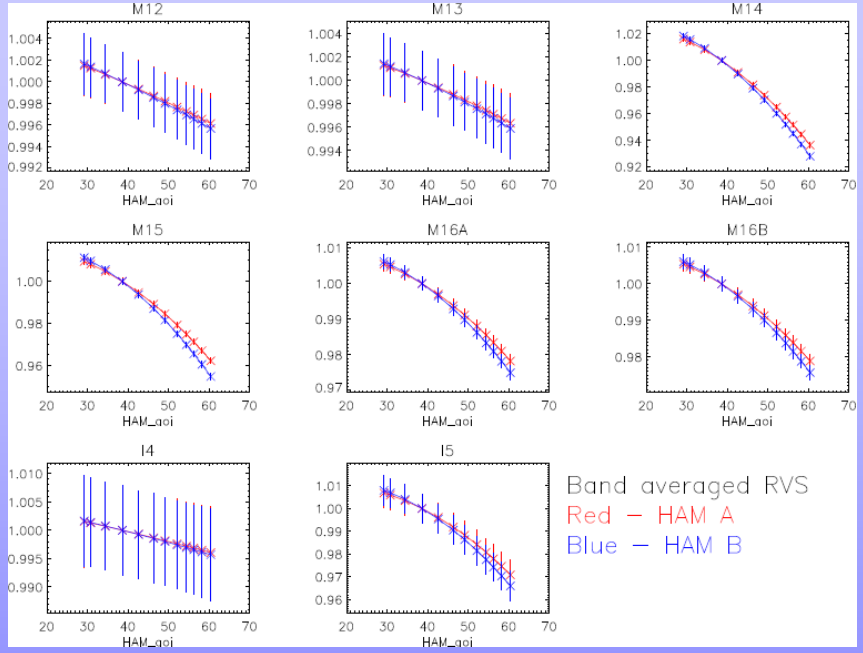


- The polarization testing was based on the SIS100 and a polarizer sheet.
- A series tests led to high quality polarization measurements with good repeatability.
- The derived polarization factors satisfy design specifications for sensitivity and uncertainty.
- The derived polarization factors vary strongly with detector and the variability depends on the scan angle.

VIIRS Response Vs. Scan (RVS)

Pre-Launch Performance





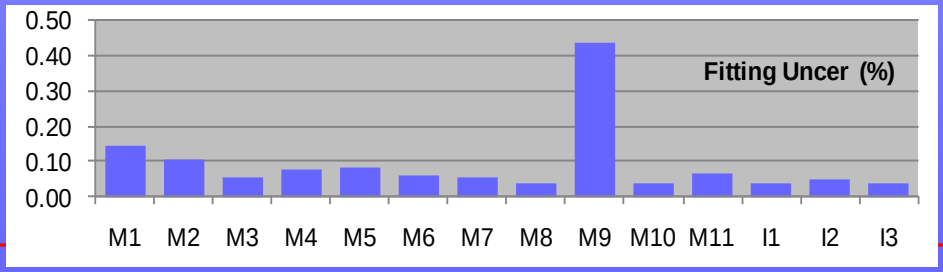
M9 was impacted by water vapor

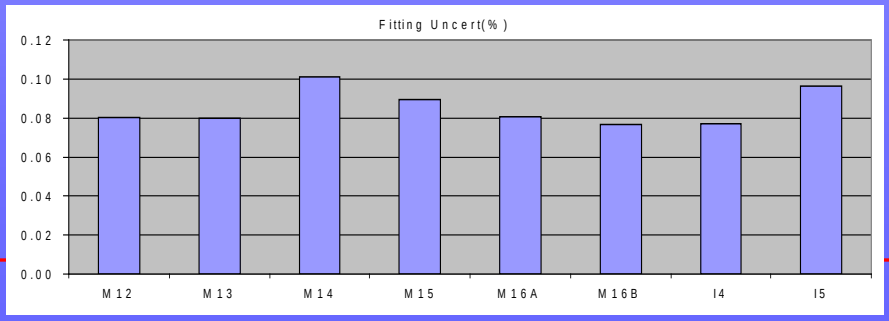
RSB Uncertainty :

Spec = 0.3%

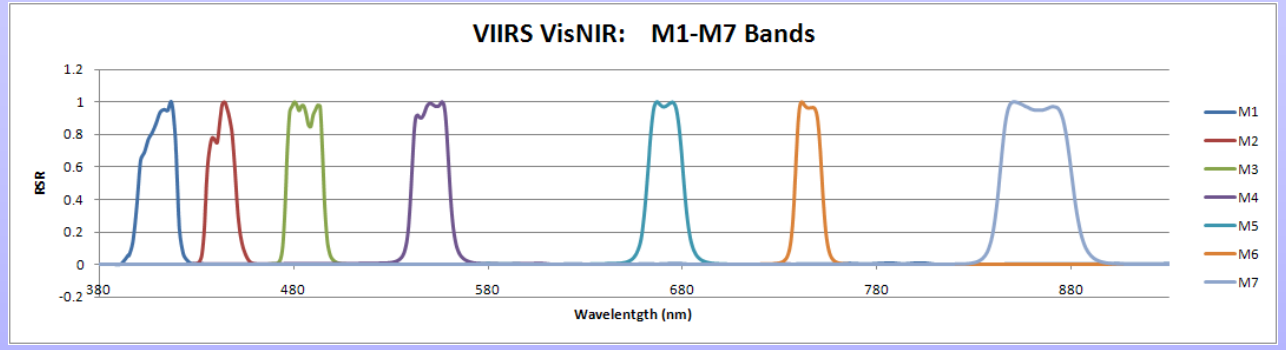
TEB Uncertainty :

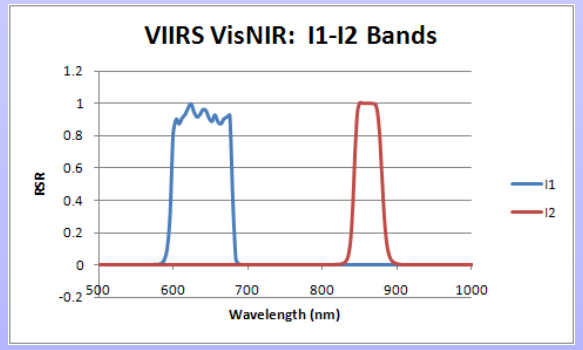
Spec = 0.2%

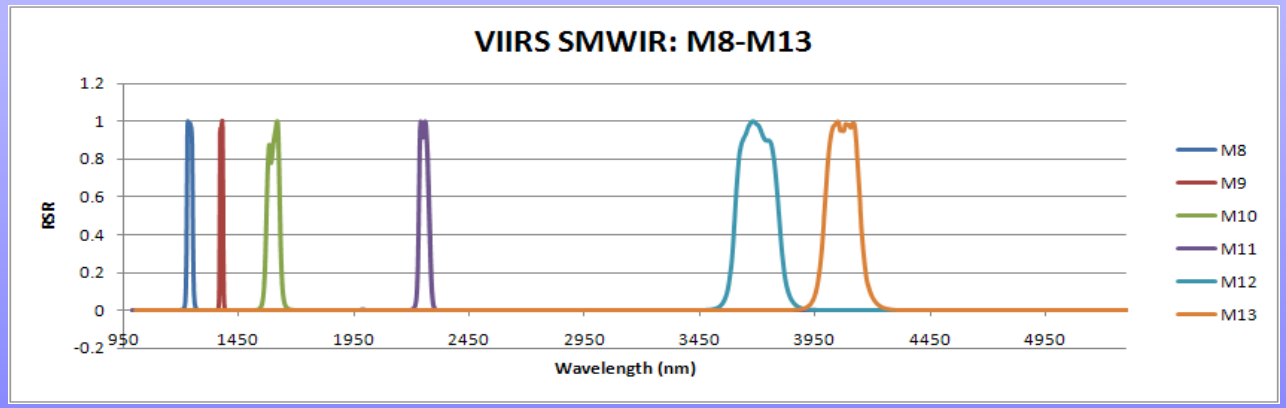


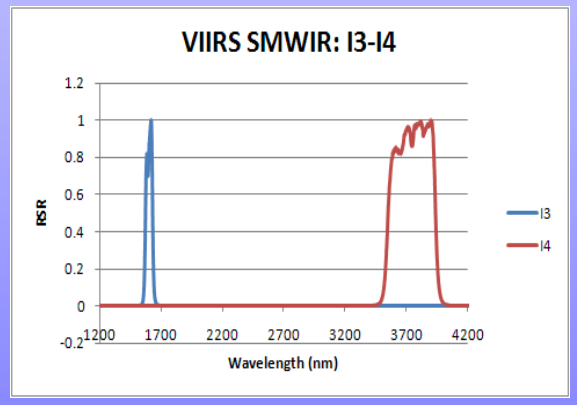


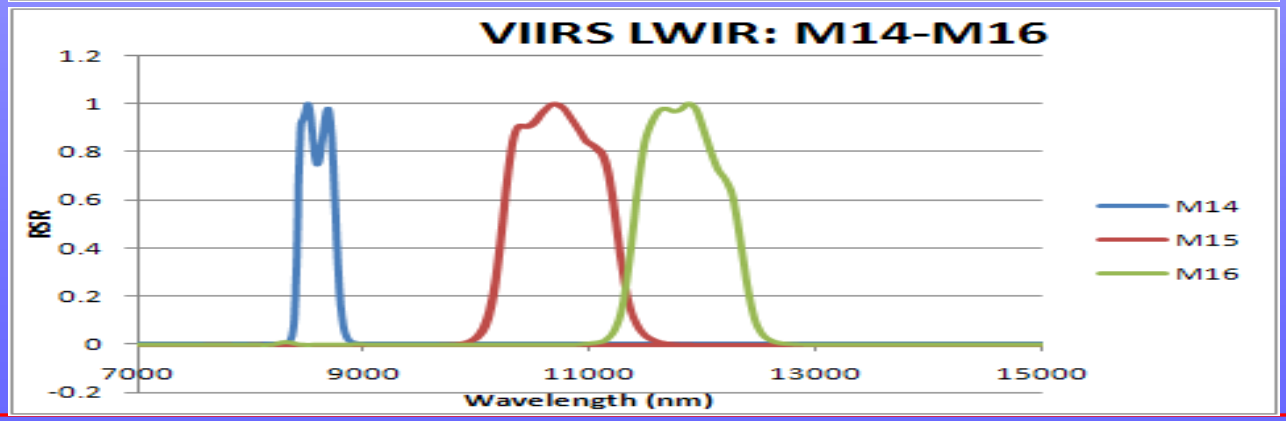
VIIRS F1 TV RSRs (SpMA)

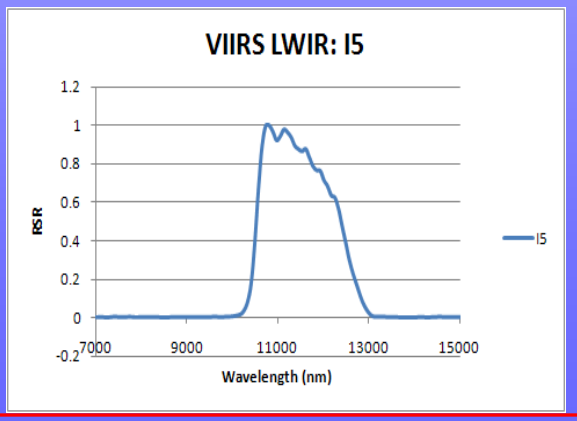




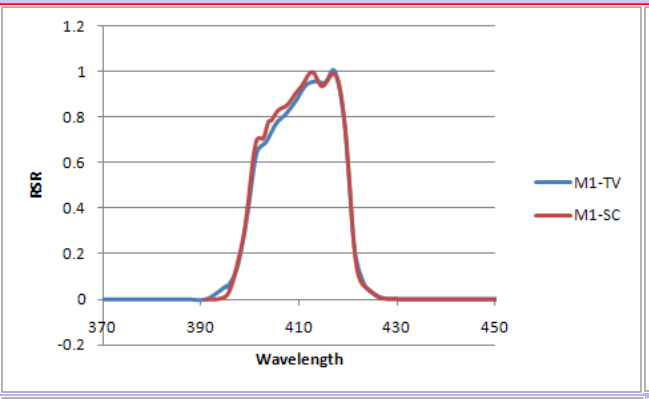


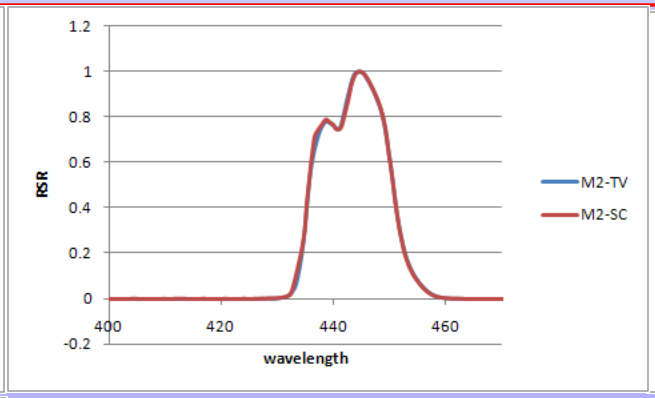


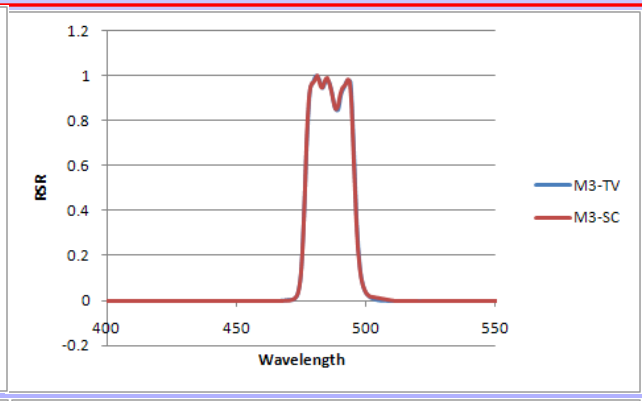


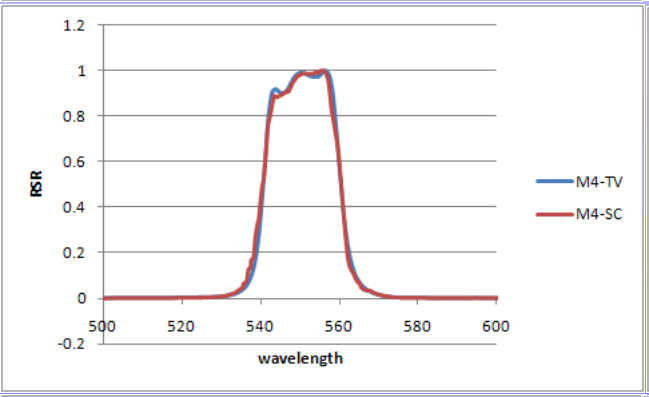


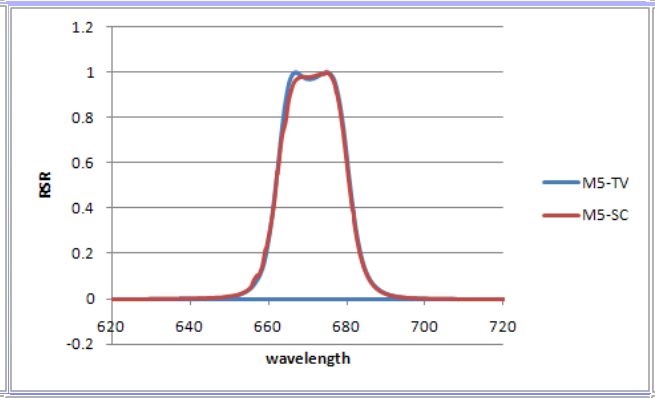
SpMA RSRs vs SIRCUS RSRs
(VisNIR bands only)

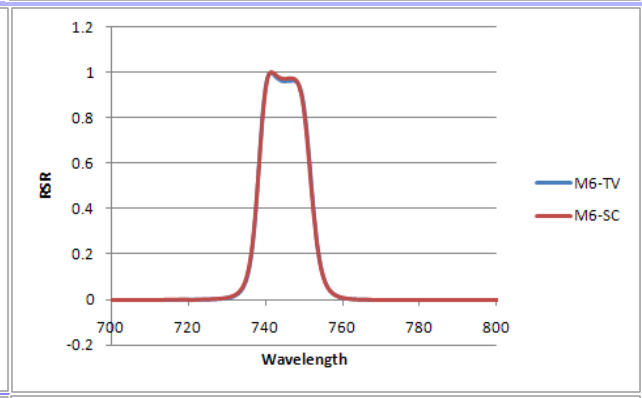


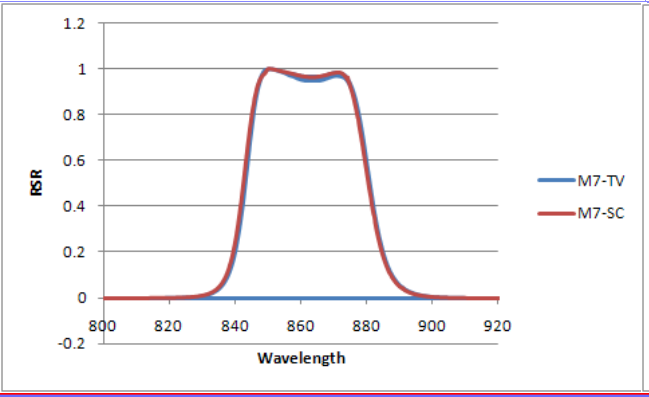


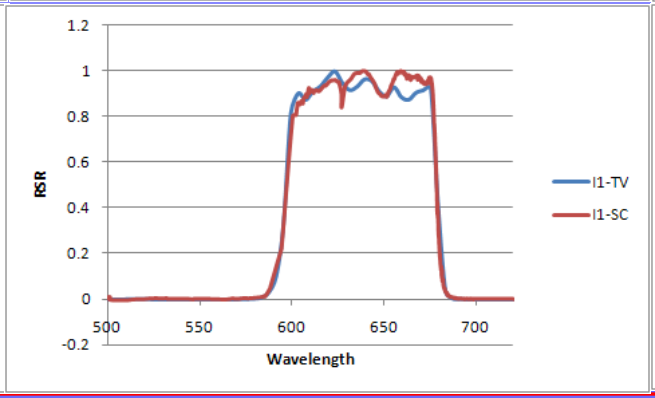


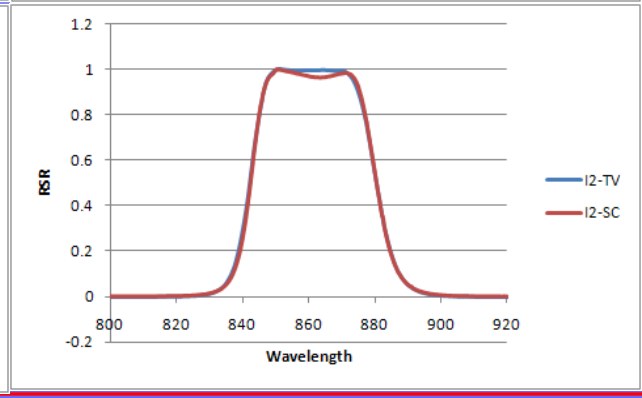




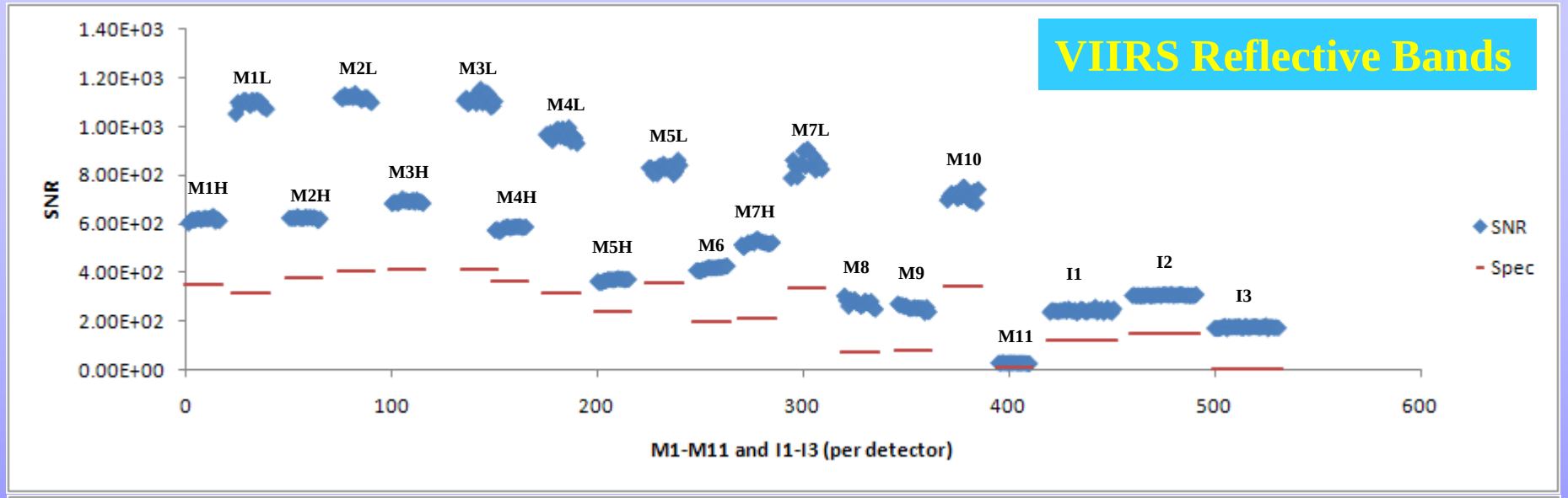


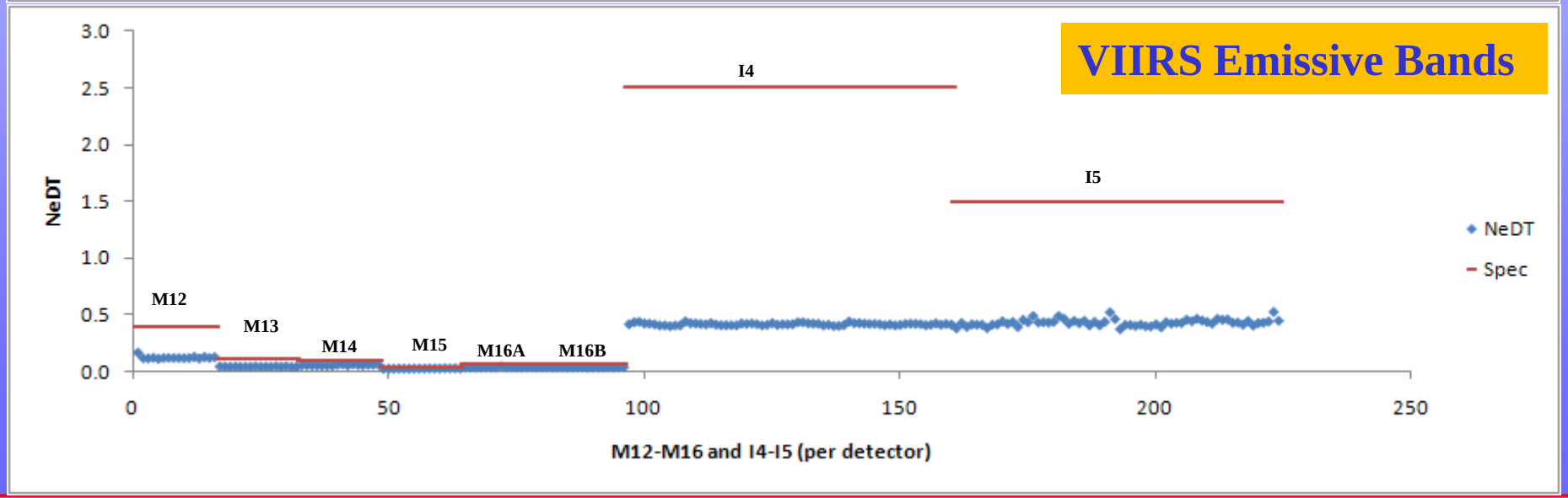






SNR and NEdT Performance

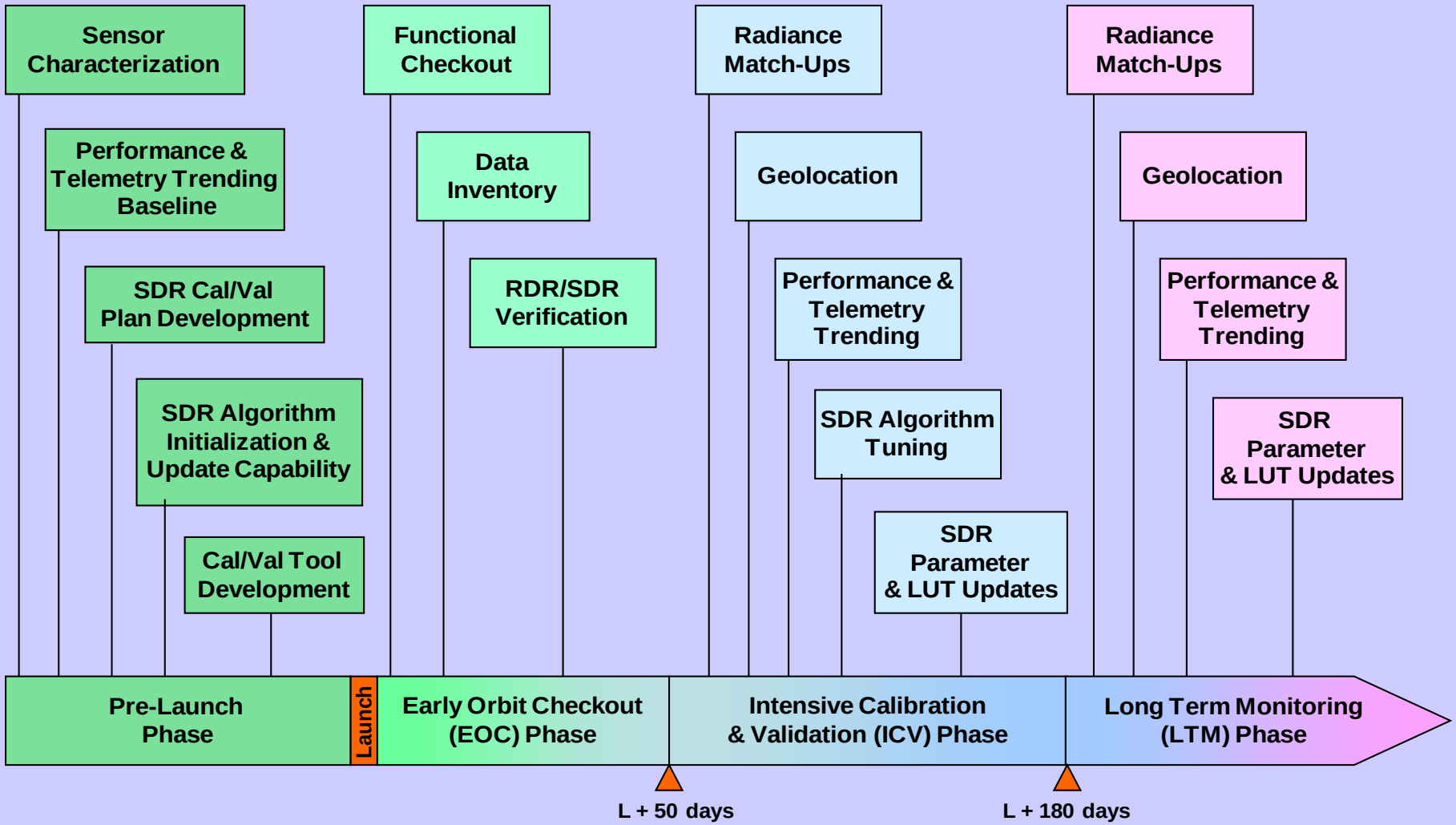




On-orbit Calibration and Characterization

- **VIIRS post-launch calibration and characterization will be performed by the SDR team managed by NOAA STAR with contributions from**
  - NOAA, NASA, Aerospace, Raytheon, UW, MIT/LL, and NGC
- **Calibration strategies and activities have been developed via an intensive government-contractor team collaboration, heavily based on MODIS lessons and experience; 54 tasks in 6 categories**
  - Functional Performance and Format Evaluation (FPF 1-7)
  - Calibration System Evaluation (CSE 1-6)
  - Image Quality Evaluation (IMG 1-4)
  - Radiometric Evaluation (RAD 1-25)
  - Geometric Evaluation (GEO 1-7)
  - Performance and Telemetry Trending (PTT 1-5)
- **NASA team will support all phases of NPP VIIRS post-launch calibration and characterization**
  - EOC, ICV, and LTM

VIIRS Cal/Val Activities by Phases



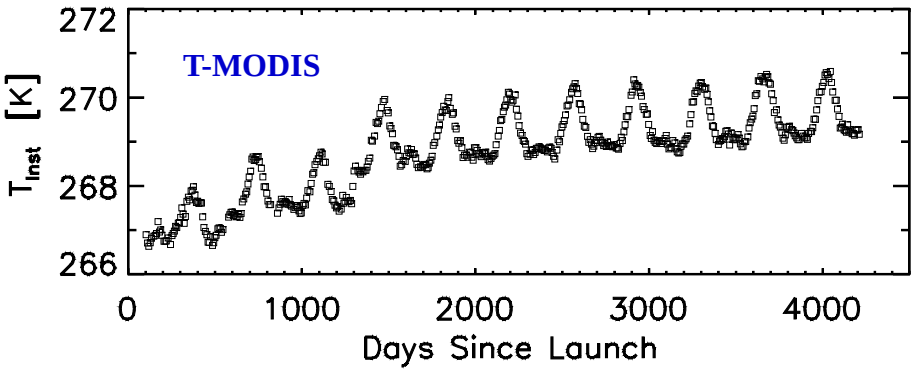
On-orbit Calibration and Characterization

- **On-board Calibrators**
  - SD and SDSM
  - BB
- **Lunar Observations:** whenever a -55º phase Moon is visible to VIIRS (assuming 10/25/11 launch, first opportunity will be day L+71)
- **S/C maneuvers**
  - All planned VIIRS maneuvers have been approved by NPP Project
  - Lunar rolls for degradation trending and reflective solar bands stability monitoring
  - Pitch-up deep space view for thermal emissive bands response vs. scan angle (RVS)
  - Yaws for SD and SD stability monitor attenuation screen characterization

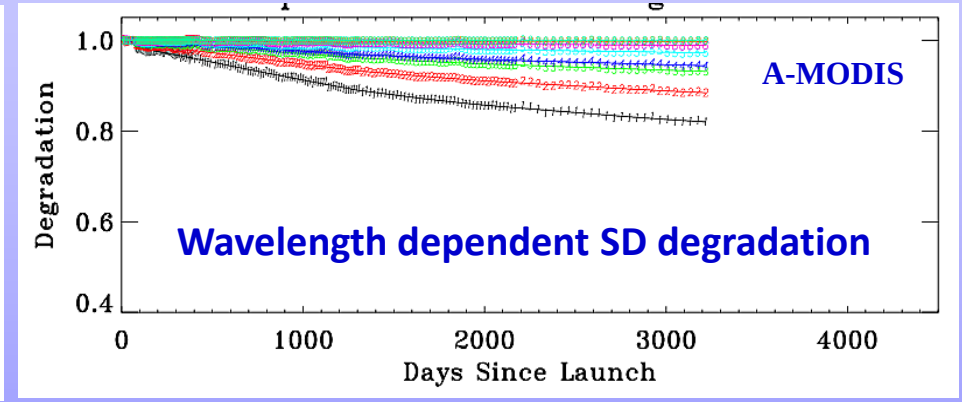
Tools have been developed and tested to support NPP VIIRS on-orbit Cal/Val planning, data analysis, and performance monitoring

On-orbit Calibration and Characterization

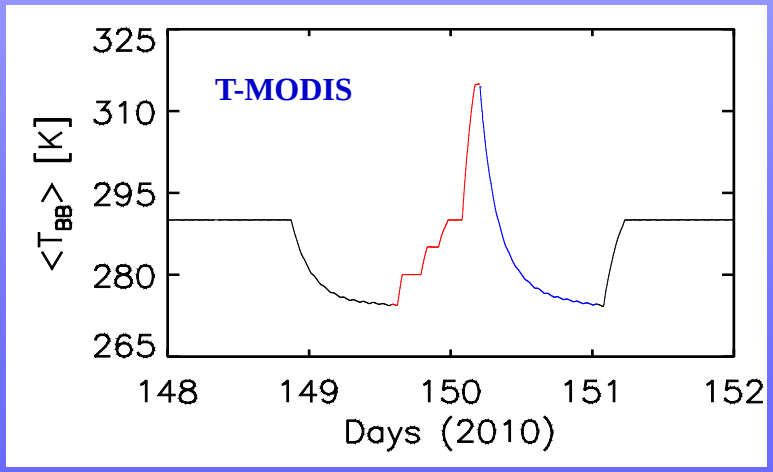
MODIS Instrument Temperatures



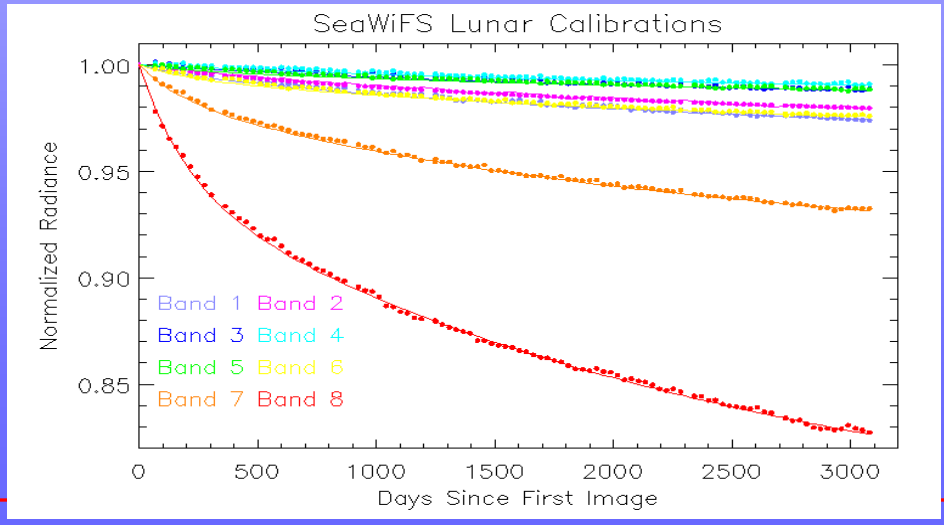
On-orbit Degradation



Blackbody Warm-up and Cool-down



On-orbit Lunar Calibration



Summary

- **NPP VIIRS test program at the instrument and observatory level is complete and has provided an extensive amount of high quality data to enable the assessment of sensor performance**
  - VIIRS performance exceeds requirements with only a few non-compliances
  - Non-compliances have been reviewed and impacts have been assessed.
- **On-orbit calibration and characterization plan**
  - In Integrated Government Team (IGT) has developed a comprehensive cal/val plan for SDR products to ensure high quality measurements.
  - Task leads and support were identified to develop and verify approx. fifty (50) on-orbit cal/val tools. We expect full readiness to support NPP Launch.
- **Launch readiness testing/rehearsal**
  - VIIRS cal/val team performed 2 rehearsals to exercise on-orbit cal/val tools and processes (July 18-22, August 22-27, 2011).
  - Both rehearsal phases were successful, and issues identified are being addressed to make sure all components critical to VIIRS cal/val are ready and fully verified.

Backup

VIIRS F1 Performance Status

Based on sensor level TV testing

Reflective Solar Band (RSB) Performance

Performance	Requirement Verification	Expected Risk to EDRs
SNR	All RSB bands meet SNR specifications with margin	Low
Dynamic Range	M1 and I2 slightly not compliant	Low
	M8 not compliant	Low
Gain Transition	Only M1 is not compliant. Margin is about -10% of Lmax.	Low
Linearity	All RSB bands meet Linearity specification with margin	Low
Uniformity	1 NeDL requirement not met for some cases	Medium
Uncertainty	All bands are meeting specification	Low
Stability	All RSB bands meet Stability requirements with margin	Low

Thermal Emissive Band (TEB) Performance

Performance	Requirement Verification	Expected Risk to EDRs
NEdT	All TEB bands meet NeDT specifications with margin	Low
Dynamic Range	All TEB bands compliant for Lmax.	Low
Gain Transition	Only M13 is slightly not compliant.	Low
Linearity	All TEB bands meet Linearity specification with margin	Low
Uniformity	All TEB bands meeting uniformity requirement (1NeDL)	Low
Absolute Calibration	All TEB bands are meeting specification with margins	Low
Stability	All TEB bands meet Stability requirements with margin	Low

Spatial Performance

Performance	Requirement Verification	Expected Risk to
Line Spread Function (LSF)	Scan DFOV is compliant for majority of M-bands and I-bands.	Low
	Track IFOV is compliant for all M-Bands and I-bands, Except M12 Det #1.	Low
	Scan MTF is compliant for majority of M-bands	Low
	Track MTF is compliant for all M-Bands.	Low
	Scan HSR is compliant for majority of I-bands	Low
	Track HSR iscompliant for all I-bands	Low
Band to Band Registration (BBR)	BBR is compliant for all band pairs, except few cases	Low
Pointing Stability	Pointing stability is compliant, except daily stability in track direction	Low

Spectral RSR Performance

Performance	Requirement Verification	Expected Risk to EDRs
Spectral Band Center	Only M4 and M16 are slightly not meeting specification	Low
Spectral Bandwidth	Only M2, M8 and M14 slightly not compliant. M16A Detectors #5-7 also slightly not compliant	Low
Extended Bandwidth	Only I5 is slightly not compliant for the upper 1% limit	Low
Integrated Out-Of-Band	Many bands are not compliant. However, OOB is well characterized	Medium-High
Band to Band Crosstalk	Many bands are not compliant. However, crosstalk characterization will support on-orbit mitigation.	Medium-High

- VIIRS F1 test program is complete and has provided good test data to assess sensor performance.
- Sensor performance exceeds requirements in most cases, and non compliances were addressed in waiver packages and impact assessments
- NASA performance assessments are beginning of life (BOL). Modeling of EOL performances are available in Raytheon Performance Verification Reports (PVRs).
- Government team finalized VIIRS F1 Performance assessments to generate on-orbit LUTs for SDR algorithm